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TITLE

REPORT ON THE PERFORMANCE OF A PROTOTYPE MULTI-MAN VAPOUR COMPRESSION COOLING UNIT

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Report on the Performance of a Prototype Multi-Man Vapour Compression Cooling Unit

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INTRODUCTION

DCIEM has funded the construction of a prototype vapour compression cooling unit to evaluate the performance of such designs for microclimate systems for aircrew.

This report describes the details of the design, outlines the performance of the unit, and suggests areas where improvements could be made.

DESIGN DETAILS

Specifications

Components

Compressor	Sankyo SD 505, with magnetic clutch removed.
Motor	1/2 HP nominal, 28 VDC Brush-type motor, Motor Products Owosso Corp.
Drive	11 tooth x 45 tooth sprockets, 3/8" Pitch chain
Condenser	Tekumseh 50801-3
Evaporator	2 - HXR 30 2 - HXR 50 Frontier
Water Pump	Shurflo Model 100-000-31 (Modified for improved cooling)
Fan	Comair Rotron Major DC
Refrigerant	R-12

Performance curves are attached for the compressor.

Overall

Outside Dimensions	30 x 30 x 47 cm
Weight	22.9 kg

The compressor chosen is reputedly the smallest automotive air conditioning compressor available. Although it is oversized for this application, it was selected because hermetic 28 VDC compressors are not available. A chain drive was used to match the compressor speed required to the motor characteristics.

The condenser was selected because of its rugged design.

This unit is normally found on commercial ½ hp condenser sets.

The evaporator initially installed was a single unit, normally used as a water-cooled condenser. Initial tests showed the single evaporator to be grossly undersized, and three more similar units were added in series.

An electronic speed control was installed for the pump and adjusted to deliver about 800 ml/min of water at 50 kPa, matching the flow and pressure requirements of 4 high performance Exotemp heat transfer shirts.

To avoid freezing and provide automatic control, a refrigerant expansion valve was installed. This adjustable valve can be set to result in a minimum water temperature a few degrees above freezing.

Performance

Figure 1 presents data gathered as the cooling unit encountered ambient temperatures of 25°C, 35°C, and 40°C.

Total rates of heat extraction from the circulating water are plotted in figure 2. As expected this rather limited data shows performance declining with lower coolant temperatures for a given ambient, and declining with higher ambient temperatures, for a given coolant temperature.

Observations of Performance

1 - Measurements of refrigerant pressure (and thus condensing temperature) and ambient air temperature indicated that the unit as it stands is limited by condenser size. Condensing temperature was as much as 30C° above ambient temperature. The performance could be improved by a more effective condenser.

2 - Similar observations of the evaporating pressure and water exit temperature indicated that the evaporator was working remarkably well. Exit coolant temperatures were commonly within 4C° of the indicated evaporating temperature.

3 - The compressor should be worked harder. It unfortunately suffers from blow-by which worsens at the higher condensing pressures needed in warmer ambients. At low speeds this parasitic loss hinders it substantially.

	COOLANT CIRCUIT #1				COOLANT CIRCUIT #2						
AMBIENT TEMP. °C	TEMP.IN °C	TEMP.OUT °C	FLOW ml/min	HEAT TRANSFER WATTS	TEMP.IN °C	TEMP.OUT °C	FLOW ml/min	HEAT TRANSFER WATTS	TOTAL HEAT TRANSFER WATTS	TOTAL CURRENT AMPS	MOTOR TEMP. °C
25	10.5	20.2	400	270	10.4	20.6	404	287	557	19.8	111
25	8.8	19.1	428	307	8.4	17.1	405	245	552	20.0	124.7
25	5.4	13.5	428	242	5.3	11.2	408	168	410	19.8	130.7
35	10.9	18.0	380	188	10.2	18.6	380	222	410	22.0	160
35	8.6	16.8	374	214	7.8	14.0	377	163	377	22.5	166
40	9.9	17.0	377	186	9.1	15.9	378	179	365		
40	8.8	16.5	385	206	7.7	13.7	387	162	368	23.5	177
40	19.0	28.0	384	240	18.0	25.9	342	188	428	24.5	159
40	18.9	27.2	384	222	18.3	26.9	342	205	427		
40	19.3	27.0	377	202	18.5	27.1	343	205	407	24.5	160
40	19.6	27.0	382	197	18.7	27.7	346	217	414		

NOTE: Pump current was 1.6A

FIGURE 1 - COOLING UNIT PERFORMANCE DATA

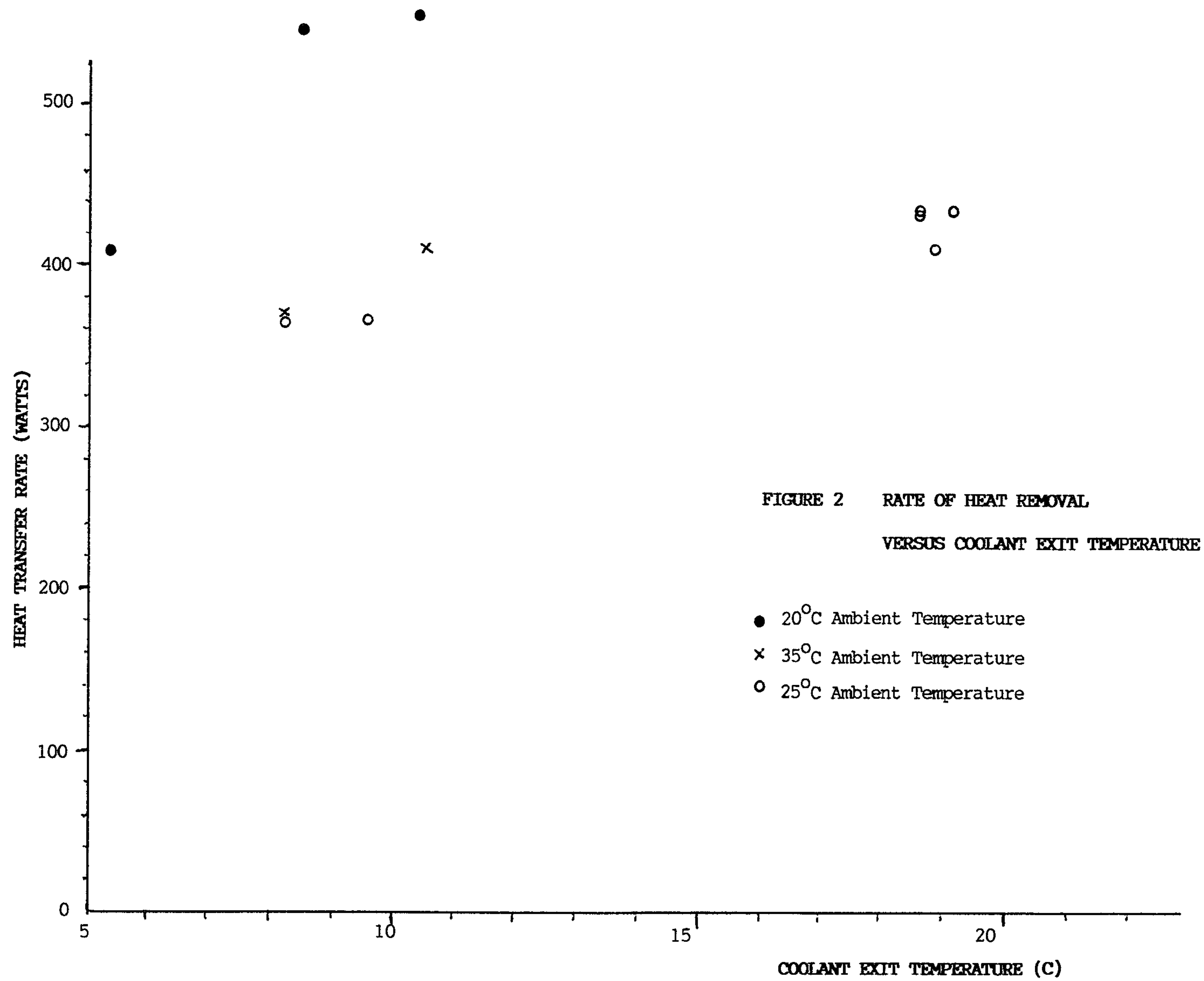


FIGURE 2 RATE OF HEAT REMOVAL VERSUS COOLANT EXIT TEMPERATURE

4 - The motor, although supposedly rated for operation in 50°C temperatures, comes perilously close to burning its winding insulation at 40°C ambient. It is also a bit too small, running at 23 Amps at 40°C versus its rated 20 Amps.

Recommendations

The condenser should be improved on. A condensing temperature within 15°C of ambient should be readily achievable.

The motor should be a more open type, better able to cool itself. It should also be capable of about 50% more power.

The chain drive, which was selected for the prototype because the ratio could be easily changed, should be replaced by a toothed belt if extended operation is intended.

A more robust coolant pump should be selected for extended operation.

Attention should be focused on weight reduction for series production units.

Conclusions

This work indicates that it will be possible to provide sufficient cooling at 40°C ambient for 4 crew members for a power consumption of less than 30 Amps at 28 VDC.

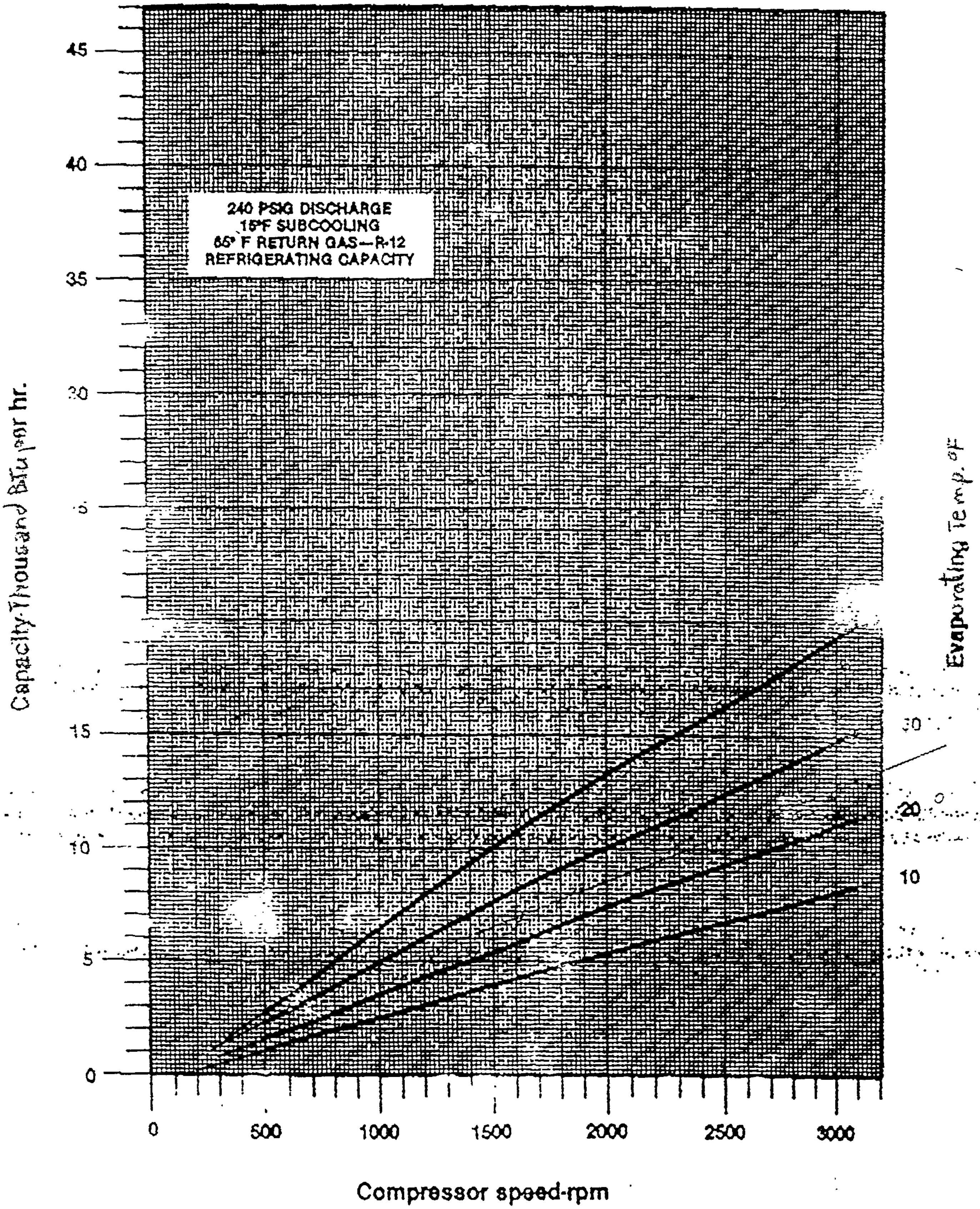
The volume of the unit can be less than 43ℓ. The weight can be less than 23 kg.

Appendix

Compressor Performance Charts

SANKYO COMPRESSOR

MODEL SD-505



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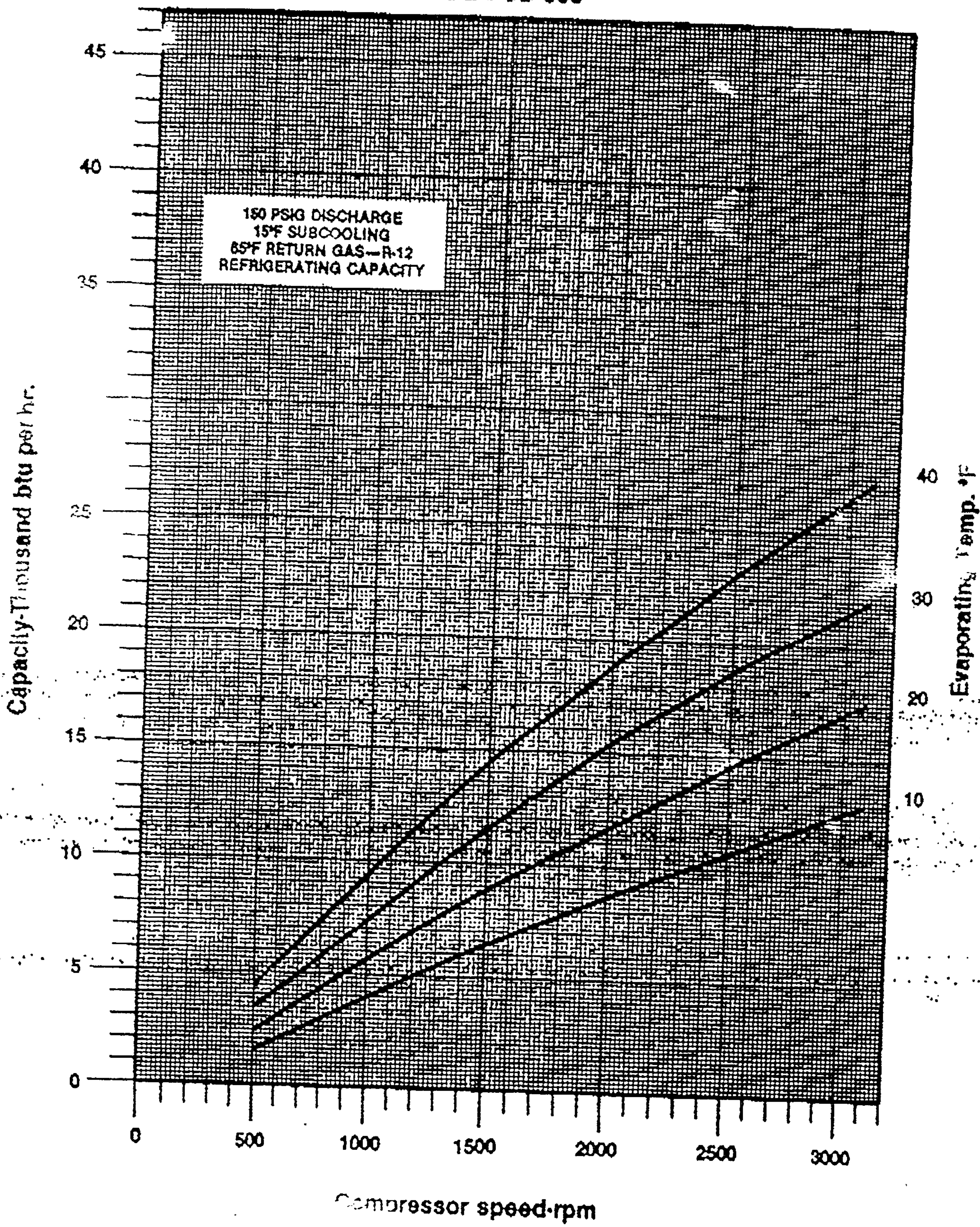
SANKYO COMPRESSOR

MODEL SD-505



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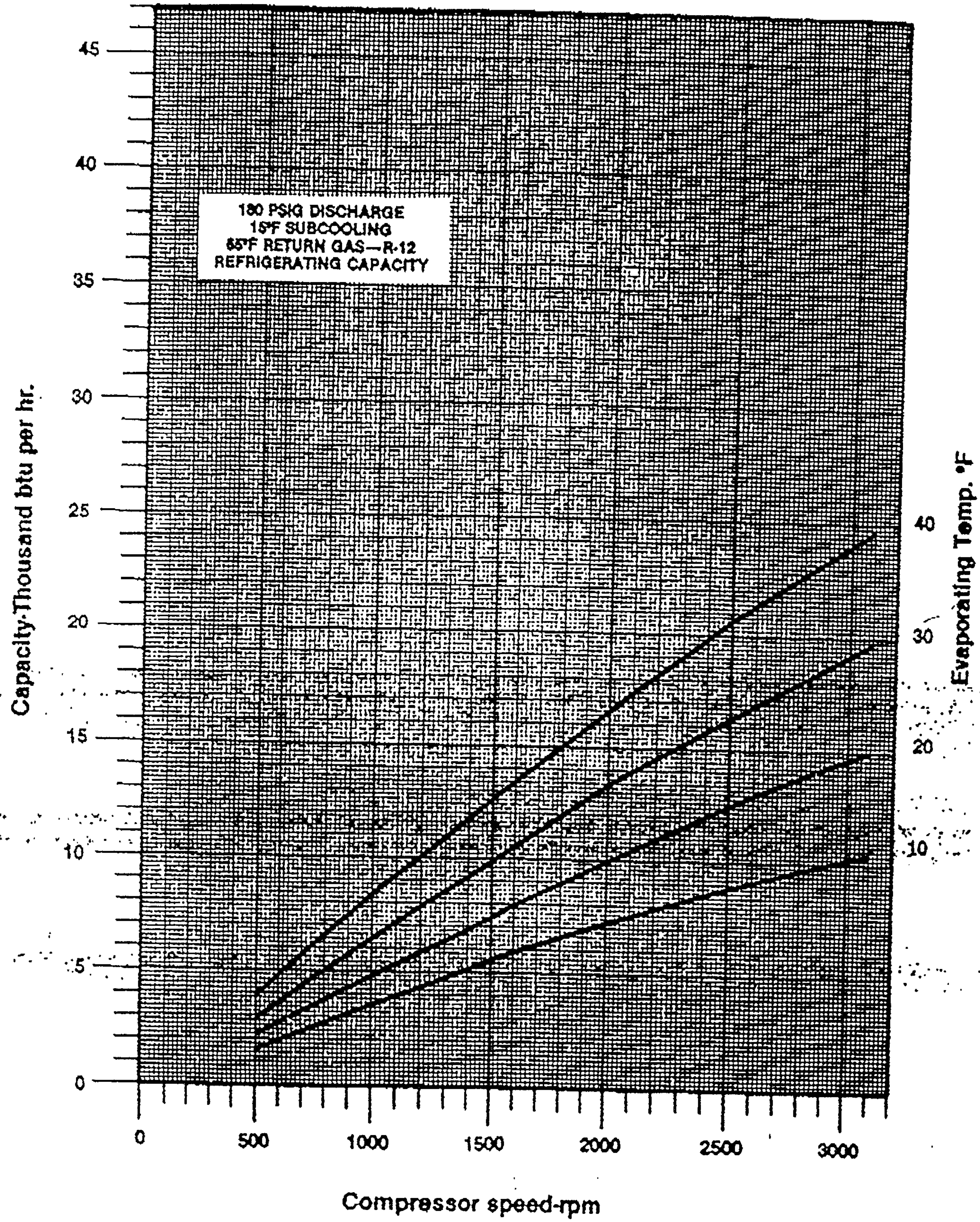
SANKYO COMPRESSOR

MODEL SD-505



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sankyo international

Operating Instructions

Prototype Vapour Compression Multi-Man Cooling Unit

Description

These instructions pertain to the operation of a prototype cooling unit assembled to demonstrate the practicality of using existing vapour compression refrigeration technology and components to condition circulating liquid for multi-man crews aboard helicopters and transport aircraft. The attached schematic shows the major components. An automotive-type shaft-driven compressor is driven by a 28VDC electric motor through a reduction chain drive. Refrigerant flows through an air-cooled condenser and a refrigerant drier to an expansion valve. This adjustable valve is set to result in a minimum evaporation temperature above the freezing point of water. The remainder of the refrigerant loop consists of a water heated evaporator, and a receiver to reduce the chance of liquid carryover to the compressor.

The heat transfer loop consists of a reservoir, pump, check valve, the water side of the evaporator, and connectors to interface with the heat transfer garments. There is also a pressure switch to shut down the pump when garments are not connected. The check valve prevents cycling of the pump in this condition.

The electrics are relatively simple. a single switch starts the motor and fan. The pump speed is controlled through an electronic pulse train generator. A potentiometer allows the pump speed to be adjusted. The compressor motor is equipped with an iron constantan thermocouple which can be used to sense the winding temperature.

Operation

1 - Connect the unit to a 28 VDC, 30A power supply. Observe the correct polarity.

2 - Fill the reservoir with water. If the unit will be run at sub-freezing temperatures, use an antifreeze mixture. A 10% solution of alcohol in water may also be used to guard against damage if freezing occurs. Such a solution will provide only moderate freezing point depression, but it will effectively protect against freezing damage by forming a slush instead of a hard ice.

3 - Connect one to three garments to the unit. Note that the compressor will automatically unload if no heat load is fed to the garments. No harm will result.

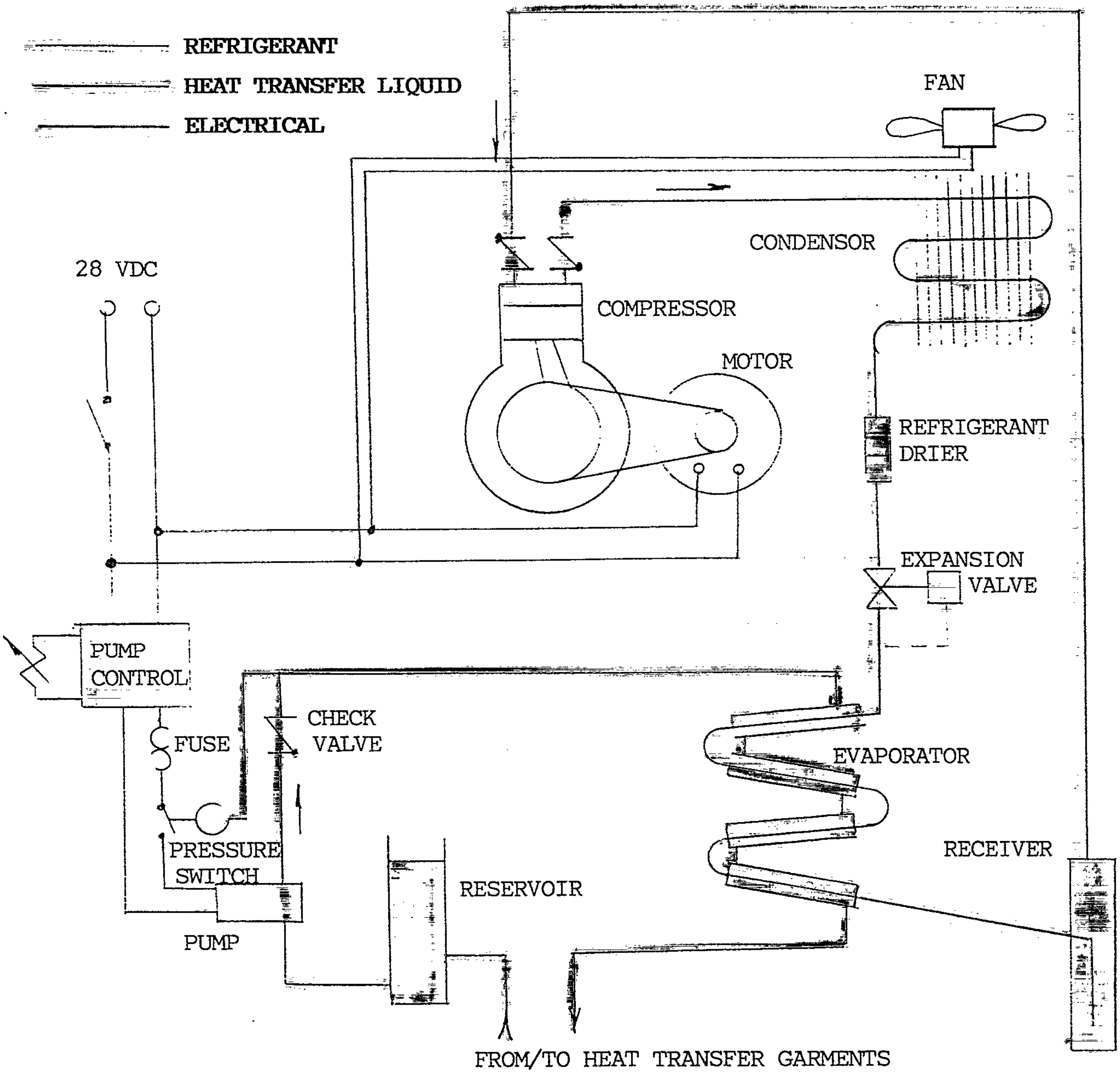
4 - Run the unit by operating the switch.

5 - The pump speed was adjusted prior to delivery through the locking potentiometer to result in the correct flow for Exotemp high performance shirts. The pump speed may be adjusted if desired, however, if the pump speed is to be increased, a voltmeter should be connected to the pump leads. Voltage in excess of 12 VDC may damage the pump.

6 - Shut down by switching off.

Caution

- Do not run the unit without heat transfer liquid in the reservoir.
- Do not exceed motor temperatures of 160°C. Damage will result. Monitor motor temperatures when operating in high ambient temperatures.
- Do not operate the unit inverted or more than 45° from horizontal.



SCHEMATIC – VAPOUR COMPRESSION COOLING UNIT

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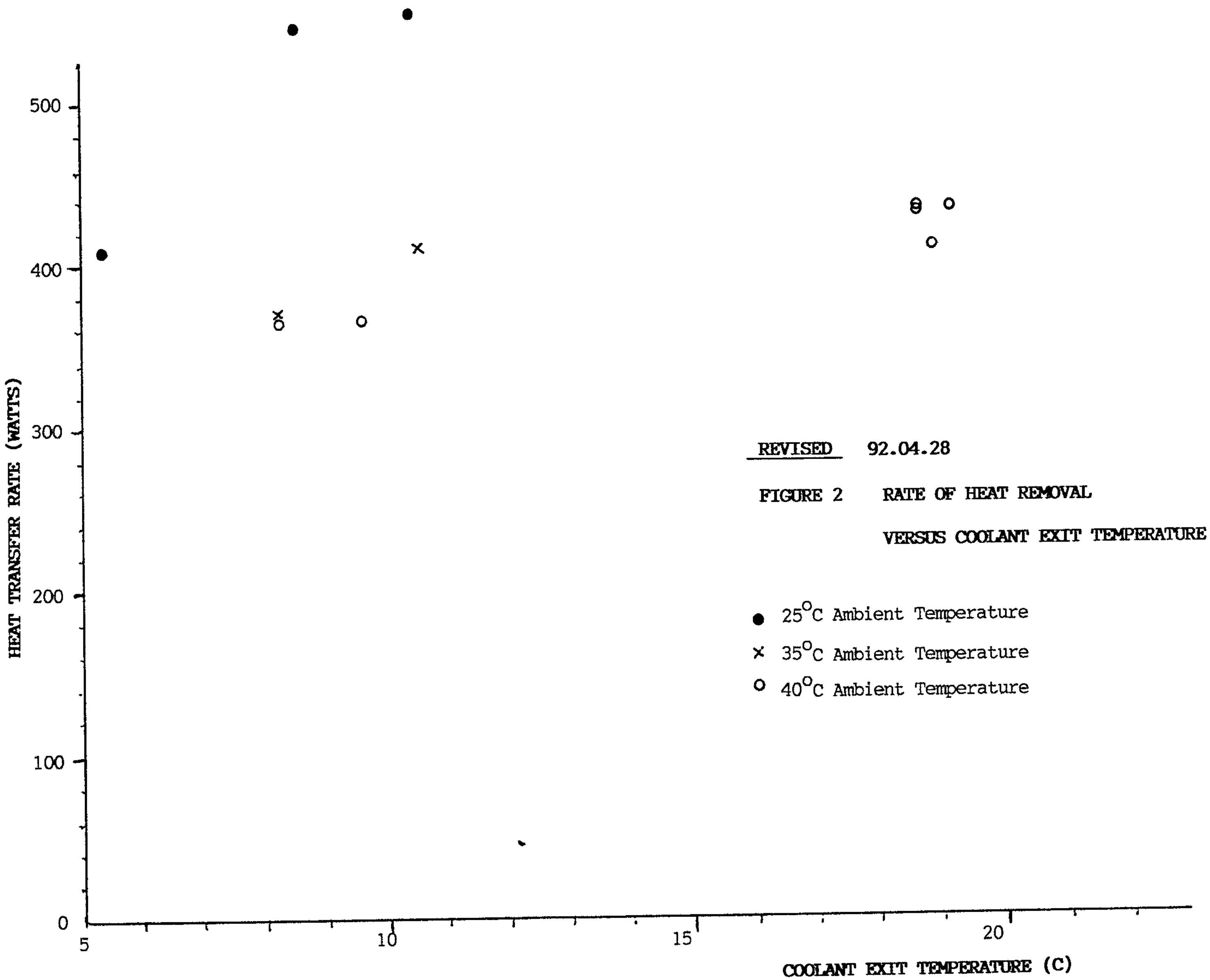

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FIGURE 2 RATE OF HEAT REMOVAL VERSUS COOLANT EXIT TEMPERATURE

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